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Methodological Appendix:
The Global Economic Burden of Non-Communicable Diseases

By the World Economic Forum
and the Harvard School of Public Health

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This document accompanies the World Economic Forum and Harvard School of Public Health report *The Global Economic Burden of Non-communicable Diseases,* which can be accessed via the World Economic Forum's website: www.weforum.org/EconomicsOfNCD. Its purpose is to provide additional details on the methods, formulae, and data sources used to construct the estimates in the report. For additional inquiries, please contact the study authors.

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Appendix A. Cost-of-illness method (Chapter 2.1)

A.1 Cancer

Model:
Methods and formulae were based off the Beaulieu et al., 2009 study and can be found on pages 57 – 60 of Appendix E.

Incidence Analysis:
The first step of the analysis involves estimating the number of new cases of cancer in 2010 and 2030. Incidence rates are from the International Agency for Research on Cancer's GLOBOCAN 2008 database, which gives incidence rates for 27 specific cancer sites in the form of the number of new cancer cases per 100,000 relevant population, by sex and age group for 184 countries and territories around the world (Ferlay et al., 2010).

Each cancer/gender/age/country incidence rate is multiplied by the United Nations 2010 estimate of the number of people in each age and gender category in each country to arrive at the number of new cases per country in 2010.

Incidence is assumed to be constant over time and is multiplied by population in 2030 (United Nations Population Division, 2011) to calculate the number of new cancer cases per country expected in that year. This is known as a "business-as-usual" scenario, in which population is the only factor allowed to vary over time.

The number of new cancer cases in "other sites" is imputed by subtracting the sum of cancer cases for all 27 unique sites from the total category "All cancers but non-melanoma skin cancer." (See equation E2 of Beaulieu et al., 2009).

Cost Analysis:
Cost figures are based on a study of site-specific cancer costs in the Republic of Korea in 2002 and adjusted for cross-country differences in health expenditures per capita and to account for inflation (Kim, et al., 2008). Costs are estimated in three distinct categories:

- Medical costs, which include the cost of medical procedures and services associated with treatment and care of cancer, including hospitalization, outpatient visits, and prescription drugs.
- Non-medical costs, which include the costs of transportation for treatment and care, costs of complementary and alternative treatments for cancer, and care-giving costs.
- Income losses, which refer to output lost or foregone by cancer patients because of treatment or disability. Estimates of income loss per case are derived from the authors' calculations and based on data from both the aforementioned Korean study and an additional study (Yabroff et al., 2008) that provided self-reported estimates of lost work days by cancer site. These figures are adjusted to account for inflation, higher costs in the first year after diagnosis, and differences in income per capita across countries. The adjusted estimate of income loss per case is then multiplied by the estimated number of cases occurring among 15-64 year olds in 2010 and 2030, adjusting for real income growth**.**

Data sources:

Cancer Incidence:
The GLOBOCAN 2008 database is maintained by the International Agency for Research on Cancer and can be accessed online: http://globocan.iarc.fr/. The methodology for GLOBOCAN 2008 is described in Ferlay et al., 2010.

Population estimates:
2010 and 2030 population estimates for each country by gender and age group - using the medium variant for population projections - are from the United Nations World Population Prospects, 2010 Revision: http://esa.un.org/unpd/wpp/index.htm

Country Income:
Country income groupings are based on the World Bank classification scheme, taken from the World Bank website in June 2011. The World Bank divides economies based on 2010 GNI per capita, calculated using the World Bank Atlas method. The groups are: low income ($1,005 or less), lower-middle income ($1,006 - $3,975), upper-middle income ($3,976 - $12,275), and high income ($12,276 or more). Specific details on groupings can be found here: http://data.worldbank.org/about/country-classifications/country-and-lending-groups

Medical and non-medical costs per cancer site:
Figures are based on data from a South Korean study (Kim et al., 2008) and adjusted for cross-country differences using data on health expenditures per capita from the World Bank World Databank and adjusted to account for inflation. To impute medical and non-medical costs per cancer site in a given country A, the costs in South Korea are multiplied by an adjustment factor equal to the ratio of health expenditure per capita in country A to health expenditure per capita in South Korea. For more details, please refer to Appendix E of Beaulieu et al., 2009.
The World Bank World Databank, available: http://databank.worldbank.org/data/home.aspx

Lost income costs per cancer site
Figures are based on data from Kim et al., 2008 and Yabroff et al., 2008. The costs are adjusted for cross-country differences in income based on GNI per capita data from the UN Statistics Division, National Accounts Estimates of Main Aggregates, inflation, greater losses in the first year after cancer diagnosis, and real income growth. Income losses are only applied to the working-age population in each country, defined as the number of individuals ages 15-64. Detailed formulae can be found in Appendix E of Beaulieu, et al., 2009.
UN Statistics Division, National Accounts Estimates of Main Aggregates:
http://unstats.un.org/unsd/snaama/Introduction.asp

A.2 Cardiovascular disease

Model:

The CVD policy model was based off the Gaziano et al., 2006 study. This model divides the costs of CVD into five broad categories: screening, primary prevention, secondary prevention, acute hospital care, and lost productivity. The analysis is restricted to data available for WHO regions[1] and is meant to be as exhaustive as possible given the data available.

Prevalence and Incidence Analysis:

Before determining costs, we first determine the number of cases in each of the 14 WHO regions.[2] Overall adult population estimates are used for screening costs. Estimates for the adult population with hypertension and elevated cholesterol are used for the primary prevention cases.[3] Prevalence and incidence rates for ischemic heart disease (IHD), stroke, and congestive heart failure (CHF) are also determined by region. Event rates for the three conditions are based on current prevalence of CVD, expected incidence rates from the prevalence of risk factors such as diabetes and smoking, and the blood pressure and cholesterol levels known for each region using a Framingham-based CVD event prediction model and confirmed by published literature. Death rates, event rates, and duration of hospitalizations are used to determine lost productivity.

Cost Analysis:

Primary prevention costs consist of the costs for outpatient visits, assuming approximately three visits per year to diagnose and manage elevated blood pressure and elevated cholesterol. We use costs provided by the WHO-CHOICE (***CHO***sing ***I***nterventions that are ***C***ost-***E***ffective) project (World Health Organization, 2005). The costs from WHO-CHOICE estimates include physician, nurse, and other staff time in addition to the cost of facilities, labs, and medication. Screening costs include the outpatient visit costs necessary to make the diagnosis for hypertension, along with an additional lab cost for determining the cholesterol level. To determine the overall number of adults with each condition that are eligible for treatment and actually receive medications and make visits to clinics, we apply estimates for awareness and treatment rates for each region from Danaei, et al., 2011.

Secondary prevention costs include clinic costs both at the primary health centre and the hospital for specialist care, lab costs, and medication costs. Treatment costs for both primary and secondary prevention are based on median costs for generic medications from the Management Sciences for Health (MSH) Drug Indicator Pricing Guide, 2009. For each region, we use estimates based on 80% population coverage in general at the health facilities. However, we take into account regional variations in treatment delivery rates for secondary prevention for stroke, ischemic heart disease (IHD), and congestive heart failure (CHF).

For the costs of acute care, we determine the number of predicted cases of IHD (angina and myocardial infarction), stroke, and CHF that would likely be admitted in the various regions, with high-income regions having a higher proportion of cases receiving hospitalized care than low-and middle-income regions. Hospital costs include an average 7-day hospitalization, including room ("hotel") costs, physicians, nurses, and other hospital personnel costs, medications, laboratory costs, and operating room or procedure time where appropriate. Treatments beyond traditional chronic medications (aspirin, beta-

[1] Regional estimates are calculated based on average regional data, as opposed to calculating and summing country-level costs.

[2] Note: WHO Member States are grouped into 6 geographic regions: AFRO (Africa), AMRO (Americas), EMRO (Eastern Mediterranean), EURO (Europe), SEARO (South-East Asia) and WPRO (Western Pacific). The six WHO regions are further divided based on patterns of child and adult mortality in groups ranging from A (lowest) to E (highest): AFRO (D,E); AMRO (A,B,D); EMRO (B,D); EURO (A,B,C); SEARO (B,D); WPRO (A,B). For more information, see WHO, Definition of region groupings.

[3] Primary prevention cases refer to the number of individuals eligible to be subjected to primary prevention costs (i.e., treating hypertension and elevated cholesterol before incidence of CVD events).

blockers, cholesterol-lowering medications, and heart failure treatments) include thrombolytic agents and anticoagulants (e.g. heparin). Procedures include percutaneous coronary interventions and coronary artery bypass surgery. Estimates on the wide range of availability and use of these procedures in different regions of the world are taken into account.

Productivity losses are estimated by first determining the annual expected number of deaths from IHD, stroke, hypertensive heart disease, and CHF. Using estimates from Leeder et al., 2004, which estimates the proportion of CVD deaths that are predicted to occur between the ages of 35-64, the number of deaths in each region is calculated, using a representative country from that study for each region. Then, assuming an average age of event of 55 in this population and a value for the regional unemployment rate, the net present value of lost wages is calculated[4]. CVD rates are assumed to be independent of employment status, which may over- or underestimate the total. In addition, lost productivity is taken into account for those with permanently disabling stroke, advanced CHF, and severe angina. Finally, lost work time for seeking care in the outpatient setting and during hospitalizations is included.

The above costs are then projected for each year between 2011 and 2030, assuming the changing age demographics based on estimates from the United Nations Population Division. For this analysis, incidence rates, risk factor estimates, and hospitalization and treatment rates are held constant, while absolute numbers are adjusted to account for increases in the adult population. The costs of managing hypertension and abnormal cholesterol values are addressed in this model, although diabetes management and smoking cessation are not.

Costs Figures:

i. Primary Prevention
    i. Health Centres: Outpatient Costs. We use the data from WHO-CHOICE and calculate the cost of 3 visits/year, 10 minutes per visit.
    ii. Lab Costs: We calculate the cost of one set of labs a year in international dollars using data from the World Bank's Disease Control Priorities Project (Mulligan J., et al., 2003).
    iii. Hypertension screening cost: average cost. We use the cost of Health Centres: Outpatient Costs (2 visits/year, 10 minutes per visit) (WHO-CHOICE data, 2005).
    iv. Cholesterol screening costs: average cost. We use the cost of 1 lab test (WHO, 2005).
ii. Secondary Prevention
    i. Health Centres: Outpatient Costs. We use the data from WHO-CHOICE and calculate the cost of 2 visits/year, 10 minutes per visit.
    ii. Hospital: Outpatient Costs. We use the data from WHO-CHOICE and calculate the cost of 2 visits/year.
    iii. Drug Costs: We use the median price for each drug from the MSH 2009 report. We then calculate the cost for an annual (365-day) supply at the appropriate dose.
iii. Acute Care
    i. Hospital: Inpatient Costs. We use the data from WHO-CHOICE and calculate the cost per admission, which we estimated is 7 days. We then use a bottom-up ingredients approach incorporating hospital bed or "hotel" costs, wages for health workers, lab costs, and medication costs for each admission.
    ii. Medical Providers' Salary: We determine the hourly wage for a medical specialist, medical officer, nurse, and health worker using the data from WHO-CHOICE. We then multiplied the wage by the hours each hospital employee contributes to a hospital admission.
        a. We use the median price for each drug at the appropriate dose from the MSH 2009 report.
        b. Tissue plasminogen activator (TPA) costs per dose are from Kent, 2004.

[4] Average disponsible wage and minimum wages by country were sourced from the OECD Tax Database and International Monetary Fund. Available: http://en.wikipedia.org/wiki/List_of_countries_by_average_wage; http://en.wikipedia.org/wiki/List_of_minimum_wages_by_country

iii. Cardiac catheterization/Percutaneous coronary intervention/Percutaneous transluminal coronary angioplasty (Cath/PCI/PTCA): average costs are derived from CVD policy model by Gaziano, et al.
iv. Coronary Artery Bypass Graft (CABG): costs are derived from CVD policy model by Gaziano, et al.

iv. Work Days Lost
    i. To obtain an estimate for the cost of number of days lost due to hospitalization, annual minimum wage estimates for representative countries for each region are selected from the IMF or OECD databases when average wage data was not available. This leads to a conservative estimate of loss productivity costs.

Demographic and Health Indicators:

i. Total population: by Global Burden of Disease region, from the World Health Organization GBD 2004 update.
ii. Percent of adults in total population: we calculate this from the United Nations World Population Prospects, 2010 Revision.
iii. Adult population: we multiply the percent of adults by the total population.
iv. CHF prevalence/IHD prevalence ratio is based on regional data from WHO.
v. Adult CHF prevalence: calculated from CHF/IHD ratio and IHD prevalence.
vi. Adults with IHD and stroke: calculated based on CVD policy model and risk factor prevalence.
vii. Adult CHF Incidence: we calculate this by: Adult CHF prevalence* (CHF incidence/prevalence ratio)
viii. Adult IHD Incidence: From CVD Model
ix. Adult Stroke Incidence : From CVD Model
x. Total CHF cases (in 000s): calculated by Adult Pop Size* Adult CHF Prevalence
xi. Total IHD cases (in 000s): calculated by Adult Pop Size* Adult IHD Prevalence
xii. Total Stroke cases: calculated by Adult Pop Size* Adult Stroke Prevalence
xiii. CHF incident cases, IHD incident cases, Stroke incident cases: calculated by Adult Pop Size* Adult Incidence
xiv. Absolute numbers of persons with disabling CHF and with stroke, respectively, calculated using prevalence and adult population size.
xv. Absolute numbers of IHD, stroke, and hypertensive deaths, respectively, calculated using prevalence and adult population size.
xvi. % receiving hypertension screening: Proportion of people aware that they had hypertension from *UnitedHealth and NHLBI Collaborating Centres of Excellence: The financial impact of three population based interventions on blood pressure management costs in 33 low and middle income countries.(Gaziano et al.; in press)*
xvii. % receiving cholesterol screening: For high-income countries we use 68% (Schober, S.E., et al., 2007) and for the LMIC countries we assume limited screening.
xviii. Patient time costs (hours, days). Both of the below variables are calculated assuming 14 days per hospitalized acute CHF, IHD, Stroke, and 3 hours per outpatient visit for primary, secondary prevention.
    a. travel time (hours)
    b. work lost seeking care (days)
xix. Primary prevention (% receiving care)
    a. We assume 20% elevated BP is treated (weighted drug outpatient visits)[5] and that 10 % of elevated cholesterol is treated (lovastatin, outpatient visits, labs).
xx. Secondary prevention (% receiving care)
    a. CHF, IHD, Stroke and Hospital Outpatient: Estimates are based on sub-regional data from WHO.
    b. CHF, IHD, Stroke Prevalence: We assume 80% of the patient population receives secondary care.
    c. We use acute hospital care for CHF, IHD and stroke. High-income countries have a higher proportion of care received than low- and middle-income countries.

[5] "Weighted drug" refers to a weighted average of drug costs for those on blood pressure treatment during primary prevention. We assumed 20% of adults with elevated blood pressure received this weighted drug costs, in addition to outpatient costs.

d. We use aspirin, Heparin (5000 units/ml and 1000 units/ml), Cath/PCI, and CABG for acute IHD. High-income countries have a higher proportion of care received than low- and middle-income countries.
e. We use tPA for acute IHD for high-income countries only.
f. We use Streptokinase for acute myocardial infarction for low- and middle-income countries only.
g. We use heparin5000 units/ml; and 1000 units/ml, and tPA for acute stroke. High-income countries have a higher proportion of care received with tPA than low- and middle-income countries.

xxi. Cost of screening for hypertension and cholesterol: calculated by multiplying the adult population by the cost of screening by the % receiving hypertension screening/cholesterol screening for each region. Regional costs are then summed to get a global estimate.

xxii. Patient Time Costs: We calculate the cost of work lost due to seeking care and travel time by multiplying the time lost by the wage lost for each region, then summing for a total global estimate.

xxiii. Primary prevention costs: calculated by multiplying the treatment for elevated blood pressure (weighted drug, outpatient visits) and elevated cholesterol (lovastatin, outpatient visits, labs) by percent of population receiving care, the number of people with high blood pressure/cholesterol and the cost of the treatment itself.

xxiv. Secondary prevention costs:
a. We calculate the cost of outpatient treatment for secondary CHF, IHD, and stroke prevention by multiplying the cost of healthcare and hospital outpatient visits by the absolute number of outpatient cases of IHD, CHF and stroke, respectively.
b. We calculate the cost of drug treatment for CHF, IHD, and stroke prevention by multiplying the cost of drugs used to treat CHF, IHD, and stroke by the absolute number of adults in secondary prevention for IHD, CHF and stroke, respectively.

xxv. Acute costs: We calculate acute costs for CHF, IHD, and stroke by multiplying the number of acute cases of CHF, IHD, and stroke by the drug, medical labour, and hospital costs expected for each acute case of CHF, IHD, and stroke, respectively. The percent of cases treated with drug and hospital treatment varies by region (in general, higher proportion of patients were treated in higher income regions).

xxvi. Lost productivity: Calculations use published data from a representative country from each WHO region for proportion of premature deaths or disabling effects from CHF, IHD and stroke, respectively. We multiply the number of lost work days for each fatal (for premature death) or disabling event and by the daily wage rate for each region. We assume ten years of income lost per premature death or disabling event, and discount future years at a rate of 3%. The proportion of events that resulted in premature death or disability varies by region.

Data Strengths and Weaknesses:

- The quality of the WHO regional data is determined by the strengths and weaknesses of the underlying data from the individual country surveillance systems.
- Our regional estimates are likely to reflect more conservative estimates and are generally accepted to be reasonable, especially in areas where little or no data are available.
- The CVD Policy model (Gaziano *et al*.) from which some of the cost estimates are derived has been validated using the NHANES population in the US.
- In general, the cost estimates are conservative, so the costs presented in the WEF-HSPH Report are likely to be underestimates of the true costs.

A.3 Chronic Obstructive Pulmonary Disease

Model:

The first stage of analysis involves the estimation of country-specific prevalence rates. Prevalence figures are imputed by conducting a regression including mean age, real GDP per capita, smoking prevalence in the adult population, and CO_2 emissions from solid fuel consumption.

$$Y = \alpha + \beta_1 + \beta_2 + \beta_3 + \beta_4 + \varepsilon$$

Where:
Y … country COPD prevalence (for existing data)
β_1 … mean age of population
β_2 … real GDP per capita
β_3 … female adult smoking
β_4 … CO_2 emissions from solid fuel consumption

Prevalence is assumed to remain constant over the time period 2010-2030; the rates were based from the WHO report on the global tobacco epidemic, 2011. However, total population varies according to population projections from the United Nations Population Division.

In the literature, it is predicted that most countries will experience increases in overall COPD prevalence (Global Initiative for Chronic Obstructive Lung Disease, 2010; Halbert, Isonaka, George, & Iqbal, 2003; Mannino & Buist, 2007; Nielsen, et al., 2009). Therefore, the estimates presented here are most likely an underestimation of the true cost-of-illness for COPD in 2030. Further prevalence rates were obtained through the PLATINO Study (De Oca, et al., 2009; Menezes et al., 2008; Nielsen et al., 2009) as well as through personal communication with R. J. Halbert, 2011.

The direct cost of illness consists of the cost of care in the four stages of COPD - adjusted based on GDP per capita for countries where data were missing - as well as that of exacerbations, which are extremely common in stages 3 and 4 of the disease. Data for direct costs of care were taken from the BOLD study (Nielsen et al., 2009). Indirect costs include lost income due to foregone productivity of people with COPD and their family caretakers. The indirect costs and direct costs are summed and adjusted upward by 3.6%, a summary cost percentage of 'other, non-personal, indirect costs of COPD' from several other studies (The Australian Lung Foundation, 2008; Nielsen et al., 2009).

Data sources:

- Mean age for country level population data: United Nations Population Division
  http://www.un.org/popin/wdtrends.htm

- Real GDP per capita for each country: Penn World Tables 7.0
  http://pwt.econ.upenn.edu/php_site/pwt_index.php

- $C0_2$ emission from solid fuel consumption – World Development Indicators
  http://data.worldbank.org/indicator

A.4 Diabetes

Model:

Estimates of the direct cost of illness are taken from the International Diabetes Federation's (IDF) Diabetes Atlas 2010, which reports estimates on a country-by-country basis (IDF, 2010; Zhang P., et al., 2010). These estimates are based on the medical care costs of people with diabetes, above and beyond those of people without. As such, they also reflect medical costs that are associated with other health conditions that are complications of diabetes. This report does not undertake to adjust the diabetes cost data for this component of double counting. For a detailed explanation of how IDF calculates the direct costs of illness, please refer to the Zhang, P., et al., 2010 study.

In the World Economic Forum and Harvard School of Public Health Report, the total costs of diabetes equal direct and indirect costs. Indirect costs in turn equal the sum of indirect costs due to disability and those due to mortality, the former consisting of lost patient labour income in all years prior to the year of death and the latter consisting of lost income in the year of death. Diabetes prevalence and mortality data for 2010 are also taken from the International Diabetes Atlas 2010, as are projections of diabetes prevalence to 2030. Diabetes mortality is projected to 2030 assuming the same ratio of deaths to prevalence in 2030 as in 2010 (International Diabetes Federation, 2010). Additional prevalence data for diabetes were based from multiple studies (Barceló et al., 2003; Hogan, et al., 2003; Kirigia, et al., 2009).

Indirect costs (i.e., lost income) in 2010 and 2030 due to diabetes-related disability are estimated using the prevalence of disability among people with diabetes of working age times GDP per working-age individual. For high-income countries, disability prevalence is estimated to be 2%, for low- and middle-income countries it is 8%, based on extant literature. GDP per working-age individual is calculated using World Bank GDP estimates for 2010.

Indirect costs due to diabetes-related mortality account only for lost income in the year of death; all deaths are assumed to occur at the start of the year, in other words it is assumed that people who die of diabetes do not work at all in the year in which they die. Total lost income is the product of the number of deaths among working-age individuals in a given country times GDP per working-age individual. GDP per working-age individual is calculated using World Bank GDP estimates for 2010.

We hold age-specific mortality rates constant and apply those to IDF prevalence projections for 2030 to arrive at mortality estimates for that year. GDP per working-age individual is calculated for 2030 by the authors of the report. The working-age population is assumed to be individuals of both sexes aged 15-64, based on UN Population Division estimates for the appropriate year.

Data sources:

- GDP Data in 2010 and projections to 2030: World Bank Database http://data.worldbank.org/

- Working-age population data in 2010 and 2030: UN Population Division's *World Population Prospects, 2010*
  http://esa.un.org/unpd/wpp/index.htm

A.5 Mental Illness

Model:

The estimated overall global cost of mental illness is partially based on data from a systematic review of the costs of mental illness (Hu, 2006). From this review, which includes studies between 1990 and 2003, national costs for mental health conditions are extracted for the United States, China, Kenya, and Australia for our analysis. Since the publication of that systematic review, national studies of the cost of mental illness were published for Canada, the United Kingdom, and France, and are included in the cost estimations (Chevruel, K., et al., 2010; Chylarova, E., et al., 2010; Jacobs, P., et al., 2010).

To arrive at the global cost-of-illness of all mental health conditions, existing cost estimates are converted to 2010 and 2030 estimates from their base year by multiplying the costs in the base year with an annual growth rate adjustment factor. This adjustment factor is calculated based on average economic growth per year between 2000 and 2010. While the average growth rate is different for each country, the annual adjustment factor is based on 1/10 of the average growth rate for each country between 2000 and 2010, as calculated based on the 7.0 version of the Penn World Tables.

These estimates are regressed on real GDP per capita to impute the data missing for other countries. The estimates assume no change in prevalence from 2010 to 2030. The regression for this imputation is shown below:

$$Y = \alpha + \beta_1 + \varepsilon$$

where
Y … country mental health costs (for existing data)
β_1 … real GDP per capita

Based on this regression that relates real GDP per capita with the mental health cost of illness in countries with available data, the cost of illness for mental health conditions was predicted for those countries without available data.

Data sources:

The figures for economic costs of mental illness were based off data from: Chevruel et al., 2010; Chylarova et al., 2010; Jacobs et al., 2010; Hu, 2006; Hu, 2004. Additionally, real GDP per capita data was collected from:

- Penn World Tables 7.0: http://pwt.econ.upenn.edu/php_site/pwt_index.php

Appendix B. Value of lost output method: EPIC model (Chapter 2.2)

Model:

The EPIC tool was developed by the World Health Organization to simulate the economic impact of diseases on aggregate economic output (Abegunde & Stanciole, 2006). The centrepiece of the model is a standard economic growth model that relates aggregate output to capital and labour inputs, as mediated by technology. NCDs are introduced into the model by assuming they deplete both capital and labour. Capital is depleted by the diversion of savings from the increase of physical capital to healthcare consumption associated with NCDs. Labour is depleted by NCD mortality (but not NCD morbidity, as indicated incorrectly in Box 9 on p. 28 of the report).

The model does not allow for human capital, endogenous technological progress (owing to R&D spending), or for the rate of savings to be influenced by NCD mortality. The model builds in an assumption that technology improves by 1% every year in every country (i.e., the same labour and capital inputs will result in 1% higher output in one year as compared with the previous year). The technology parameter (denoted by A in the equation below) needed to implement the model is contained within EPIC for 101 countries. This parameter was imputed for the remaining 68 countries based on the relationship between income per capita and the technology parameter.

In our study, the economic burden is estimated for five conditions in 169 countries for 2011-2030: ischemic heart disease, cerebrovascular disease, diabetes, COPD and breast cancer. The estimates are based on WHO projections of the mortality trajectory associated with these five conditions, as well as on WHO estimates of labour force participation rates and imputed rates of technological progress constructed as part of this project.

The EPIC model basically involves the simulation of a Solow (1956) growth model, where production of country i in year t, i.e. the country's gross domestic product (GDP), follows a neoclassical production function of the form

$$Y_{i,t} = A_{i,t} K_{i,t}^{\alpha} L_{i,t}^{1-\alpha},$$

where Y denotes output, A is a productivity parameter measuring efficiency in production, i.e. the technological level of a country: K is the aggregate capital stock, i.e. it represents all the machines, buildings, and infrastructure used in the production process; L is the stock of labour in the economy, i.e. it represents all individuals applying their skills in the labour market; and α represents the capital share. The productivity parameter A is assumed to grow exogenously and independently of NCDs in each country while the output elasticity of capital α is constant and hence also independent of NCDs. The first equation via which NCDs enter the model is the capital accumulation equation

$$K_{i,t+1} = s\, Y_{i,t} - \chi C_{i,t} + (1-\delta) K_{i,t},$$

where s represents the savings rate, i.e. the fraction of final output invested in the creation of new capital; C represents the treatment costs of the disease; χ is the fraction of these costs financed out of an individual's savings; and δ is the rate of depreciation. This equation describes the evolution of the aggregate capital stock, which depends positively on the savings rate and depends negatively on the costs of curing the illness under consideration as well as on the fraction of these costs paid out of savings. The second equation via which NCDs enter the model is the evolution of the workforce

$$L_{i,t+1} = \sum_{a=15}^{R-1} (1-\mu_t^a) L_{i,t}^a + \beta_{i,t-14} N_{i,t-14} \prod_{a=1, s=t-(15-a)}^{14} (1-\mu_s^a),$$

where a refers to age, μ_t^a represents the cohort specific mortality rate of individuals at age a, L_t^a is the cohort size of individuals at age a, $\beta_{i,t-14}$ represents the birth rate at time $t-14$, $N_{i,t-14}$ refers to the

population size at time at time $t-14$, and R is the retirement age. The first term of the right-hand side of this equation represents the evolution of the workforce for all persons who belonged to it in the previous time period and the second term represents the cohort size of the young who are entering the workforce at time t. NCD-related mortality enters the cohort-specific death rates and therefore exerts its impact on the economy via this labour force channel. Note that it is assumed that only individuals who are older than 15 years actively participate in the labour market.

The EPIC model provides results for five conditions (ischaemic heart disease, cerebrovascular disease, diabetes, chronic obstructive pulmonary disease (COPD), and breast cancer), which are then scaled up using data from the WHO's Global Burden of Disease Study (2004, updated in 2008) to reflect the losses associated with the four main NCDs (cardiovascular diseases, cancers, chronic respiratory diseases, and diabetes). We use information on DALYs (Disability Adjusted Life Years) associated with each disease to reflect the relative contribution of each condition in the EPIC model. The scaling is implemented by calculating the proportion of DALYs in a particular domain (e.g., cancer) that are accounted for by the relevant disease in EPIC (breast cancer in this instance). Similarly, we use WHO GBD data on mental illness DALYs to construct estimates of economic losses from mental health conditions. The mental health scaling factor is calculated by obtaining the ratio of DALYs accounted for by the 4 NCD domains to DALYs accounted for by mental health conditions. Scaling factors are calculated for each country-income bracket.

Data sources:

- World Bank World Development Indicators & Global Development Finance database: http://databank.worldbank.org/ddp/home.do?Step=12&id=4&CNO=2

- Penn World Tables 7.0: http://pwt.econ.upenn.edu/php_site/pwt_index.php

- United Nations Population Division: http://www.un.org/esa/population/

- World Health Organization Global Burden of Disease database: http://www.who.int/healthinfo/global_burden_disease/estimates_country/en/index.html

Appendix C. Value of a statistical life method (Chapter 2.3)

Model:

The VSL approach attempts to estimate an individual's valuation of his/her own life on the basis of the amount of money he or she is willing to accept to confront marginal increases in mortality risk, or on the amount of money he or she is willing to pay for goods that marginally reduce mortality risk.

VSL estimates are taken to be the value of life of a representative median-aged member of the corresponding national population. For example, consider a population in which life expectancy at birth is 80, median age is 30, and VSL is US$ 3 million. Suppose further that a 50-year-old dies unexpectedly and suddenly. This death contributes 30 DALYs, and an economic loss of US$ 1.8 million (= [30/(80-30)] * US$ 3 million = $60,000 per DALY). In addition to this approach to valuation, which is based on estimates in the literature, DALYs have also been valued at one and three times income per capita; these rules of thumb are adopted in the Report of the WHO Commission on Macroeconomics and Health, 2001.

VSL estimates are typically constructed from either stated preference data (i.e., survey responses) or revealed preference data (e.g., market wage premia associated with different risks of injury or death). Economists generally prefer to rely on revealed preference data. The standard approach involves specifying and estimating the parameters of a wage equation of the following type (cf. Viscusi and Aldy, 2003)

$$w_i = \alpha + H_i'\beta_1 + X_i'\beta_2 + \gamma_1 p_i + \gamma_2 q_i + \gamma_3 q_i WC_i + p_i H_i'\beta_3 + \varepsilon_i,$$

Where
w_i … is the wage rate of worker
i, α …represents the constant term
H and X …are vectors of personal characteristics and job characteristics, respectively
p_i …are the fatal risks associated with the particular job
q … are the nonfatal risks of a particular job
WC …represents compensation benefits for workers suffering a job-related injury
ε …is a serially uncorrelated error term with mean zero, and a prime denotes the transpose operator.

The parameters to be estimated are α, β_1, β_2, γ_1, γ_2, γ_3, and β_3. The crucial parameters γ_1 and γ_2 reflect the wage compensation required to make individuals willing to accept marginal increases in fatal and nonfatal risks. For example, if each individual is willing to accept a wage premium of $\Delta w_i = \gamma(\Delta q_i)$ for a marginal increase Δq_i in fatality risk, then a pool of $1/\Delta q_i$ such individuals is collectively willing to accept $\Delta w_i/\Delta q_i$ in return for an expected number of fatalities of $\Delta q_i * \left(\frac{1}{\Delta q_i}\right) = 1$. Thus, this pool of individuals values a statistical life at $\frac{\Delta w_i}{\Delta q_i} = \gamma$.

Constructing the VSL estimates/projections requires estimating VSL for a large group of countries. This is done in this report by regressing VSL estimates (in US$ 2000) for 12 countries reported in Viscusi and Aldy (2003) on GDP per capita (in US$ 2000) and life expectancy at birth (from the UN Population Division). The parameter estimates are then applied to estimates of GDP per capita in 2010 (2030) and life expectancy data in 2010 (2030) for all countries to impute VSL estimates for countries not covered in Viscusi and Aldy (2003).

Constructing the VSL estimates/projections requires the estimation of DALYs in 2010 and 2030. This was done by (1) fitting a zero-intercept cross-country regression of DALYs for the six different categories of health conditions in 2004 (the most recent year for which data are available) on 2004 population (and its square), the share of population aged 65+, and GDP per capita in 2004 (in exchange rate terms); (2) estimating GDP per capita in 2010 (2030) by applying the average annual growth rate during 2000-2009 to GDP per capita in 2005; and (3) using the estimated parameters from the regression to extrapolate 2004 DALYs to 2010 and 2030.

The individual estimates of the value of a DALY for each country (one times income per capita, three times income per capita, and VSL divided by the difference between life expectancy and median age) are translated into estimates of national economic burden by multiplying the value of a DALY in each country by an estimate of the DALY burden of disease in that country. As such, the CMH1, CMH3 and VSL figures reported in this study may be interpreted as the total future cost of incident NCD cases in 2010 (2030). Separate analyses are conducted for five specific NCDs: cardiovascular disease, chronic respiratory diseases, diabetes, cancer, and mental health, and also for a category of all NCDs. In terms of 2004 DALYs, the five conditions – CVD, COPD, diabetes, cancer and mental health – account for 55% of all NCD DALYs. The aggregate figures reported are based on the 155 countries for which the requisite data are available. Omitted countries tend to have extremely small populations.

Data Sources:

Along with data from the 2003 Viscusi & Aldi study, the following online databases were accessed to produce the economic burden figures:

- World Bank World Development Indicators & Global Development Finance database: http://databank.worldbank.org/ddp/home.do?Step=12&id=4&CNO=2
- United Nations Population Division: http://www.un.org/esa/population/
- World Health Organization Global Burden of Disease database: http://www.who.int/healthinfo/global_burden_disease/estimates_country/en/index.html

Appendix D. Caveats

Some important caveats apply to the results presented in this report.

- First, the estimates refer to the dollar impact of future NCDs, *not* the cost of inaction. To avoid the full $47 trillion price tag, 100% of all five NCDs would have to be postponed beyond 2030 with no increase in others. Doing such an exercise is not realistic, nor would it yield meaningful results. The estimates presented in this report are intended to capture the dollar costs associated with current projected future trends in NCDs, including direct medical and non-medical costs and indirect costs, such as lost income. Expressing the cost of NCDs in dollar terms is meant to garner the attention of economic policymakers, and perhaps to spur them to action.

- Second, all of the methods used by these studies are sub-optimal: They all rely on assumptions that are less than ideal and on data that are far from perfect.

- Third, the set of NCDs studied is not comprehensive; not included, for example are vision and hearing disorders, digestive diseases, and musculoskeletal diseases.

- Fourth, the various methods used in the report (COI, value of lost output, and VSL) are sufficiently disparate that their results cannot be compared with each other.

- The estimates are simply intended to provide a ballpark idea of the cost of NCDs, to complement estimates of their impact on morbidity and mortality. Better data and further refinement of analytical techniques will yield more accurate estimates.

Appendix E. References

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